Neuro-Opinion

Gender bias in (neuro)science: facts, consequences and solutions

Jessica Schrouff[1,2], Doris Pischedda[1,3], Sarah Genon[1,4], Gregory Fryns[1], Ana Luísa Pinho[1,5], Eliana Vassena[1,6], Antonietta G. Liuzzi[1,3], Fabio S. Ferreira[1,2]

[1]Women in Neuroscience Repository (WiNRepo) Board
[2]Centre for Medical Image Computing, University College London, London, UK
[3]Center for Mind/Brain Sciences (CIMeC), University of Trento, Rovereto, Italy
[4]Institute of Neuroscience and Medicine, Forschungszentrum Jülich, Jülich, Germany
[5]Parietal Team, Inria, CEA, Paris-Saclay University, Paris, France
[6]Donders Institute for Brain, Cognition and Behaviour, Radboud University, Nijmegen, Netherlands

Corresponding author: Jessica Schrouff, admin@winrepo.org, 1 Gower street, WC1E 6BT, London, United Kingdom

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INTRODUCTION

Women neuroscientists (please note that we refer to all who identify as such) are still underrepresented in various aspects of academic life. The efforts of the community to mitigate this issue are growing but can elicit adverse reactions (Moghaddam & Gur, 2016). In this opinion paper, we discuss the different approaches that have been taken at institutional, organizational and individual levels to counter gender bias and aim at addressing unfavorable comments. We base our reasoning on empirical data and on the feedback received after the release of the *Women in Neuroscience Repository* (WiNRepo, see Supplementary Table S1.a), an initiative we created to increase the visibility of women in neuroscience. While this feedback originated mainly from oral conversations and was not rigorously quantified, we believe the frequency of the comments justify their discussion, as performed in (Moghaddam & Gur, 2016). The aim of this piece (supported by a list of signatories, see Supplementary Table S2) is therefore to 'debunk the myths' related to gender bias and to affirmative actions in academia, as well as to propose concrete measures that can been implemented to counter such bias.

FACTS

"All this is not necessary"

The first feedback we received was that 'all this' -referring to actions promoting awareness such as repositories of women in science or awards for women in Science, Technology, Engineering and Mathematics (STEM)- was not necessary as gender bias is behind us. Unfortunately, as discussed in the next sections, there is ample evidence that gender bias is still present in neuroscience and that women's careers and the community as a whole could benefit from a more diverse field.

While proportions of students in STEM at the undergraduate level are roughly similar between men and women, the gap between male and female representation increases with seniority of the position (Schiermeier, 2018; Shen *et al.*, 2018). In addition, women are paid less given the same degree and field of work as men (Barbezat & Hughes, 2005; Ministry for Women, 2018). For example, in 2017 the gender pay gap at University College London was 17.5%, close to the national average of 18% (University College London, 2017), this gap being partly driven by a lower proportion of women in senior roles (only 37% women in the higher quartile pay grade). This evidence illustrates that there are fewer women at senior positions in academia and that they are typically paid less than their male peers (Joëls & Mason, 2014).

Multiple and complex contributing factors interplay to drive this gender discrepancy at senior levels (Shen *et al.*, 2018). Among those, the rate of career switching is higher for female post-doctoral researchers who are planning to (or already) have children than for men in similar circumstances (Goulden *et al.*, 2009). Women might also encounter a number of additional obstacles, preventing them from reaching more senior positions (Bain & Cummings, 2000). These include: a lower acceptance rate for papers with a female last author (Murray *et al.*, 2018); lower recognition of their contribution (Macaluso *et al.*, 2016; Feldon *et al.*, 2017); lower acceptance rate for funding (Pohlhaus *et al.*, 2011; Kaatz *et al.*, 2016; Sheltzer, 2018); lower rate of invitation to conferences or workshops (Nittrouer *et al.*, 2018) (S1.b) and lower chances of being hired for tenure-track positions at the same competence level (Steinpreis *et al.*, 1999). Part of these obstacles may be further sustained by the underrepresentation of women in the peer-review process (Murray *et al.*, 2018) and on 'deciding bodies', as there is a tendency for homophily, i.e. a same-gender bias, for both men and women (Helmer *et al.*, 2017).

In neuroscience, this combination of factors leads to female underrepresentation in various aspects of academic life (illustrated in Figure 1 and Supplemental data). Women author significantly less papers as first ($p=3.9590e-04$) or last contributor ($p<e-20$) than men. They are awarded significantly fewer prizes (including 'young investigator' awards, $p=1.0539e-05$) and appear significantly less as speakers in departmental seminar series ($p=3.9355e-17$) and conferences (invited or contributed talks, $p=5.7349e-80$). These data illustrate the gap in female representation between early and late career stages when comparing proportions of female first (mean: 49.11%) and last (mean: 31.32%) authors. While we are not disentangling the causes of this underrepresentation, it is interesting to note that since 2014 the rate of female trainees (students and postdocs) attending the Society for Neuroscience meeting oscillated between 49% and 50%, displaying a balanced pool of young candidates. Over the same period, only 30 to 32% of faculty attendees were women, with no clear upwards trend. Please see Supplementary Materials S3 for details on data collection and analysis.

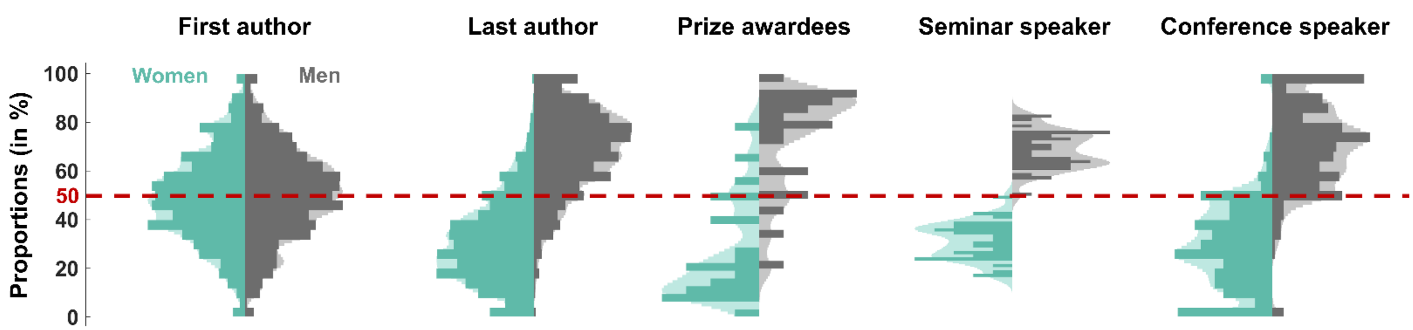

Figure 1: Histogram of proportions (in percentage) of women (green) and men (gray) in different aspects of neuroscientific academic life: first and last journal authors (n=1760, considering 176 journals over 10 years: 2009-2018), prize awardees (n=23), seminar speakers (n=38, considering 8 seminars over the academic years 2012 to 2016) and conference speakers as invited or contributed talks (n=295 conferences between 2015 and 2018).

CONSEQUENCES

"As long as the job is done..."

The second comment we received was "I don't really care if there is a bias as long as the job is done." Unfairness set apart, this argument does not hold in research and academia. Indeed, research is a creative process and the collective intelligence of a group depends on the higher social sensitivity exhibited, on average, by women (Woolley *et al.*, 2010). Diverse teams have also been shown to outperform homogeneous groups in innovation, flexibility, problem-solving, and decision making (King, 2005).

Underrepresention of a group may also have implications at the community level, since people tend to study people like them, to the detriment of other genders, classes and races that are part of our society. This becomes apparent in the medical field: for example, women's health is understudied as women were less represented in (or even excluded from) clinical trials (Vlassoff, 2007). In addition, the results of many neuroimaging studies come from target populations of highly educated white people (LeWinn *et al.*, 2017). Assessing and preventing bias is important not only for the affected groups, but for the population as a whole: studying female and male groups separately instead of mixed in (un)equal proportions would highlight specific traits in each gender (Holdcroft, 2007). Ensuring adequate representation of diverse groups and studying the effects of gender (among other variables) on the phenomenon of interest can thus improve treatments and prevention techniques for all.

As a result of existing human biases, artificial intelligence is biased as well. When trained on a large corpus of text, a machine learning model will associate *man* with *doctor* and *woman* with *nurse*, or *man* with *engineer* and *woman* with *homemaker* (Bolukbasi *et al.*, 2016). A new field of research is now dedicated to try to correct for this bias (S1.c). As machine learning for health data is becoming increasingly popular, we need to ensure that the same type of bias (e.g. due to biased experimental designs) will not influence the model's outcome as this would limit the use of such technology in 'real' clinical settings. Therefore, not only should we aim at resolving the bias issue, we also need to remember past biases to avoid their incorporation into future technologies.

SOLUTIONS

Addressing gender bias would thus be beneficial for science and academia. Solutions have been proposed to tackle different aspects of gender bias at the institutional, organizational and individual levels. Some of them are summarized in Table 1 and discussed below. We focus on actions that have been or can easily be implemented by the neuroscience community, while acknowledging that these are only partial solutions to the global and complex issue of gender bias.

Table 1: Summary of some actions (non-exhaustive list) that can be taken at the institutional, organizational and individual levels to promote gender balance in the field.

Institutions	Organizations	Individuals
• Actively collect and share data to define and evaluate new policies • Implement quotas (cascading model for hires) • Consider gender balance when awarding prizes or fellowships (e.g. through tandem nomination) • Implement "stop-the-clock" policies for parents • Implement double-blind reviewing when relevant (e.g. grant applications, journal papers)	• Favor diverse proposals • Require gender-balanced nominations for all organizing committees and reviewer pools • Search for candidates on lists or repositories • Consider gender balance when awarding prizes or fellowships (e.g. through tandem nomination) • Provide childcare or other family-friendly measures • Implement double-blind reviewing for paper	• Be aware of your own and others' bias • Speak out when observing gender biased events/behaviors • Sign up on repositories or encourage female colleagues to do so • Submit recommendations for female scientists (directly to organizations or on repositories) • Attend bias training sessions

• Organize bias training sessions	submissions and awards	

At the institutional level

Universities, funding agencies and scientific journals have an important role to play (Asplund & Welle, 2018). For instance, institutes and universities can organize bias training sessions for male and female scientists to raise awareness (Asplund & Welle, 2018). They can also favor work-life balanced environments (S1.d) and take childbearing into account when awarding fellowships or hiring (e.g. through "stop-the-clock" policies, S1.e) as women typically have a larger responsibility in pregnancy and breastfeeding, but also in caretaking due to biological, prejudicial, and often socially driven childcare demands (Calisi, 2018). Scientific journals can implement double-blind reviewing to mitigate any potential gender bias during peer review (Budden *et al.*, 2008; Bernard, 2018). All institutions can also collect and share data on various aspects of their functioning (e.g. student enrollment, reviewing panels, etc.) to establish new policies to drive gender balance.

One popular strategy in this respect is to introduce gender quotas. These are regulations that require a certain proportion of women in a given position (e.g. percentage of new hires over a certain period of time, invited speakers at conferences, winners of an award). Quotas can be binding (i.e. with consequences in case of non-compliance) or voluntary (also referred to as *targets*), implicit or explicit. They were introduced in various domains of the general society (e.g. in politics (Besley *et al.*, 2017)) to counterbalance male dominance. As in all processes that aim at correcting a bias, a larger counter-effect needs to be imposed to obtain equilibrium. In this sense, quotas have also been referred to as 'positive discrimination' or 'affirmative action' and are seen as a temporary process to obtain gender balance after a 'transition period'.

In academia, quotas can be implemented in a variety of ways (Wallon *et al.*, 2015) (S1.f). For example, a *cascading model* can be encouraged for new hires, where the quotas reflect the proportions of female candidates at the level below the open position (e.g. proportions of post-doctoral researchers define quotas for lectureships). Fellowship schemes can require *tandem nominations*, where each institution must suggest two candidates for a fellowship, one being a woman (S1.g). Quotas have elicited many reactions, which we discuss below.

"Quotas are unfair"

This type of comment reveals a deeper concern: will these measures lead to the opposite situation, where women are favored independently of their skill levels? This concern may also be associated with a fear of increased competition.

As mentioned above, women face more obstacles as compared to their male counterparts, which tends to result in less competitive resumes. In addition, women might underestimate their scientific competence (Dunning *et al.*, 2003) and therefore their resumes may misrepresent their qualification/experience when compared to a man's. Furthermore, skill judgment is subjective: studies have shown that with identical resumes, men will be assessed as more qualified and hirable than women (Wennerås & Wold, 1997; Steinpreis *et al.*, 1999; Moss-Racusin *et al.*, 2012). These findings suggest that favoring a woman over a man with 'equal competence' might mean to hire the best candidate.

The fear about increased competition is understandable: with more women scientists being visible, there are more suitable candidates for the same job. However, a case study on Swedish politics has shown that qualified men were not displaced (Besley *et al.*, 2017). Hence, quotas and the increased presence of women on the job market should not worry men that are a good fit for the job in question. Furthermore, the introduction of quotas led to an increase in the overall level of competence (Besley *et al.*, 2017), suggesting that quotas can be beneficial for the project/institution as a whole.

"Was I selected because of the quotas?"

This point was specifically made by women scientists: quotas tend to hurt their self-confidence, as the value of their work may be questioned, and the reason for their success be attributed to their gender (also mentioned in (Moghaddam & Gur, 2016)). Unfortunately, we do not have the answer to this question. However, given the evidence discussed above, it is unlikely that an unqualified woman would be given an opportunity. We would also like to stress that, whatever caused the opportunity, women in positions of power can act as role models, which would eventually attract more women and lead to a more diverse field.

Quotas are a popular measure in place to increase diversity in institutions. They are now also present at the organizational level, especially at conferences.

At the organizational level - Conferences

Diversity of speakers is becoming a criterion in the selection of keynote lectures, symposia, workshops or educational courses at conferences. Typically, no well-defined numbers or proportions of female speakers are enforced, but proposals with an appropriate representation of minorities are favored (see e.g. Society for Neuroscience call for symposia, Organization for Human Brain Mapping educational courses). Organizers are however not always able to submit proposals that are diverse in gender. The reasons cited are multiple:

"There are not many female scientists in this field"

As mentioned before, there are indeed fewer women at senior positions than men. Many would however still be suitable candidates as invited speakers, program committee members, etc. despite their low visibility. To help with this issue, multiple initiatives have been created, mostly as lists or repositories of women in science. In brain science, more than 1500 women from all countries and levels of seniority are registered on the following lists: Anne's list (S1.h), Women in Brain stimulation (S1.i), 500 women scientists (S1.j) or our WiNRepo (S1.a). We believe these resources can be helpful when searching for suitable female candidates but acknowledge that using repositories requires more effort (finding candidates, checking their references and publications) than sending an invitation to someone already known in the field. To mitigate this issue, some initiatives (e.g. WiNRepo) now include a 'recommendation system', where all scientists can leave a comment after having attended a talk by a female neuroscientist member of the repository.

"All the women we invited declined"

As female scientists are less visible, it is likely that the same people are repeatedly solicited and thus will decline some of the invitations (Moghaddam & Gur, 2016). Nonetheless, women were shown not to decline more talk invitations than men (Nittrouer *et al.*, 2018). We recommend inviting women that are outside the small circle of repeatedly solicited scientists to avoid this potential situation (e.g. using repositories). Mentioning the specific scientific contribution that elicited the invitation could potentially help avoid the question “Why was I invited?”. More generally, highlighting the suitability of the scientific, professional or educational background of the researcher for the symposium or educational event could help clarify the legitimacy and relevance of the speaker’s inclusion for attendees and invited researchers.

Quotas should be considered not only when inviting keynote speakers to an event: nominations for the organizing committee should be gender balanced, as well as for the reviewer pool, and for awarding prizes. The decision-making structures need to include (at least) a female representation that reflects the current base rate in the field for these measures to have a lasting impact. We however acknowledge that this might lead to an extra work burden for the senior female scientists who will be requested to sit on multiple panels and committees (Vernos, 2013). While we hope that the imperfect solution of quotas is temporary, when successfully implemented (preferentially in combination with other affirmative actions), they can lead to a more diverse representation (Moghaddam & Gur, 2016; Irish Research Council, 2018).

Break down the barrier for women attendance

Attendance of women in scientific international events is crucial for networking, visibility and dissemination, key steps that underlie the development of a research career. However, the critical period encountered in the “junior” career stage frequently coincides with the period of early childcare for young parents and of pregnancy and breastfeeding for women. The difficulties for parents, in particular women, to attend conferences have been highlighted several times. Calisi and a Working Group of Mothers in Sciences (2018) have discussed these difficulties and already made concrete suggestions referred to as “CARE” for 1) Childcare, 2) Accommodate families, 3) Resources, 4) Establish social networks. Offering childcare at conferences is the first and probably the most important recommendation for conference organizations. We however acknowledge that the cost of childcare facilities can make it unaffordable for many small conferences. Independently of child care facilities, all conferences should accommodate families, for example by promoting children’s attendance at conference dinners. Additional facilities should be organized for breastfeeding women, such as dedicated rooms and fridges for expressed milk. The Society for Neuroscience conference can be pointed out as an example of fruitful endeavor in that regard (Grens 2017). Finally, while all those facilities require small or larger financial/material investment, conferences can organize social networks platforms for parents to self-help as a community. Such platforms have the additional benefit of becoming a networking opportunity for scientists with young children. In addition to these four measures, we would recommend avoiding organizing events during critical school periods (e.g. beginning of the academic year) as much as possible.

Overall, we have presented several complementary initiatives as solutions at the institutional and organizational levels. Nevertheless, society cannot evolve at the institutional level without parallel evolution of individuals' mindset and effort. A collective is made of individuals, who each have the ability to raise awareness on gender bias and foster diversity in their organization.

At the individual level

All scientists can contribute to a more diverse field. In practice, most of us are implicitly subject to biases (Raymond, 2013; Asplund & Welle, 2018). A first and key step is to be aware of our (see S1.k for a free online test) and others' biases and act accordingly. Women can register on repositories to improve their visibility and should consider accepting opportunities that might have been triggered by a diversity search. While this might feel uncomfortable, such opportunities are great career advancements and the occasion to act as role model for the future generations.

In addition, all scientists can speak up when observing gender-biased events or behaviors. For instance, when invited to an event, one can check the diversity in the organization and target audience of the event. Both men and women have declined to speak at certain gender-biased events (see these pledges, S1.l). In this case, we believe the answer should be constructive, with a list of suggested female candidates. We also found that using interrogation could communicate the issue without being accusing (e.g. "I cannot locate the name of the women speaking at this event. Are you still awaiting responses?").
To ease the selection of speakers for events or other opportunities, one can also consider submitting recommendations for female scientists directly to organizations or on repositories, as the WiNRepo.

Beyond conference organization, diversity should also be promoted for other scientific activities, such as when looking for collaborators for projects or in grant writing. When declining invitations (e.g. talks or peer-reviewing articles), we suggest recommending male and female alternative candidates equally often.

Some organizations or individuals have also launched specific initiatives to target gender bias in their field. A successful example is the *Women in Machine Learning Workshop* (S1.m) that evolved from a side event at a renowned machine learning conference to an organization with chapters in many parts of the world.

All female events

It is however easy with events targeting gender bias to encounter an opposite problem: male underrepresentation. While potentially beneficial for women (especially in terms of networking), women-only events are not optimally designed to address the issue of implicit gender bias. Indeed, discussing gender bias with only the affected community cannot solve the problem (Parmar 2013). Such events also tend to exclude male attendees whereas there are still many more men in positions of power. Ignoring the difference these men could make if they were promoting diversity in their field is hindering changes in this direction. Thus, both men and women could foster progress by attending such events.

CONCLUSION

We have outlined evidence showing the existence of a gender bias in (neuro)science and proposed some possible solutions at different levels. Whether action is taken at the institutional, organizational or individual level, we would like to emphasize that addressing gender bias should always be approached in a non-blaming manner, unless in the case of clear misconduct or conscious discrimination. Non-constructive or blaming statements, whether true or not, only hurt the discussion.

We, the present generation of neuroscientists, men and women alike, have the responsibility to provide a field of equal opportunities for the upcoming generations.
Finally, we would like to conclude on a positive note: although there is still a long way to go to change the male dominant culture (Holman *et al.*, 2018), there is a rise in awareness of the problem and the situation is slowly improving (Joëls & Mason, 2014) (Figure 2). We firmly believe that pursuing the current efforts while bringing men and women together will be the key towards a fairer and more creative research community.

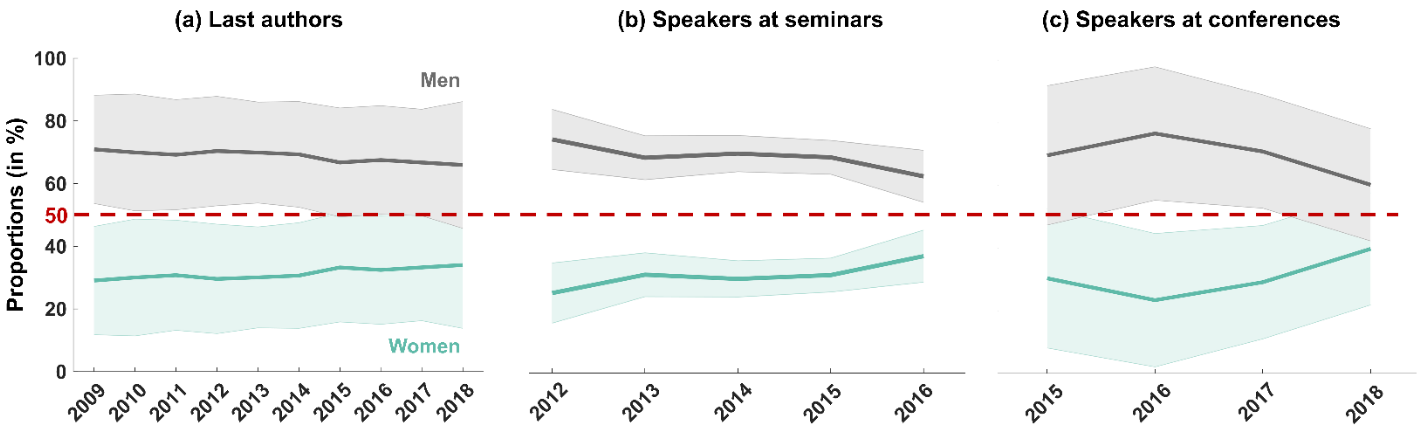

Figure 2: Proportions in percentage of women (green) and men (gray) as **(a)** last authors of journal papers (Wilcoxon Rank Sum test comparing 2009, n=176, to 2018, n=176 : p=0.0152), **(b)** invited speakers in seminar series (comparing 2012, n=6, to 2016, n=8 : p=0.0293), and **(c)** speakers (invited or contributed) at conferences over the years (comparing 2015, n=30, to 2018, n=108 : p=0.0062). Plots represent averages with ± 1 standard deviation.

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AUTHOR CONTRIBUTION

J.S., S.G. and D.P. wrote the paper, J.S. and G.F. collected and analyzed data, D.P., S.G., A.L.P., E.V., A.G.L. and F.S.F. provided extensive comments on the text.

LIST OF ABBREVIATIONS

STEM	Science, Technology, Engineering and Mathematics
WiNRepo	Women in Neuroscience Repository

DATA AVAILABILITY

All the data used in this piece are available as .csv files in Supplemental Material.

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